Paraná Basin as basement in the northern region of the Pelotas Basin: evidence from seismic and magnetic data analysis

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Abstract

Seismic and magnetic data analysis of the northern region of the Pelotas Basin were developed in order to understand the relationship to Paraná Basin, which in that region seems to extend towards the ocean. The studied geologic indicators suggest that in pre-rift times in fact the Parana Basin extended further eastwards, now lying deeply buried below the sedimentary succession of the Pelotas Basin. The present paper deals with the evaluation of this issue, discussing seismic and magnetic data which support that assumption.

Introduction

The Pelotas Basin, at the Atlantic Margin of southernmost Brazil (Fig. 1), had a relatively rapid rift phase, where the fissural volcanism of the Serra Geral Formation was immediately followed by the lava extrusion linked to the a very rapid process of rifting, which resulted in extensive layers of basalts labeled the Imbituba Formation, and by the appearance of the first basalts of the initial oceanic crust, forming a succession of inclined packages which in seismic lines form a series of inclined reflectors called seawards-dipping reflectors (SDRs).

These peculiar reflectors have been described for the Pelotas Basin by several authors (*e.g.*; Fontana, 1996; Oreiro, 2008; Holz *et al*. 2008; Dariva *et al*., 2008). SDRs are interpreted as basaltic flows and volcano-clastic rocks extruded near or above sea-level immediate prior to and during the first stage of the rifting (*e.g.*, Eldholm & Grue, 1994; Hinz, 1998; Franke *et al*. 2006; Schnabel *et al*, 2008) and hence are a precise criterion for demarcation of the first oceanic crust.

In the northern part of the basin, it seems that the basement of the Pelotas basin is formed not by crystalline rocks, but by the sedimentary succession of the Paraná Basin, which is topped by the basalts of the Serra Geral Formation, ending the succession of the Paraná Basin (Dias *et al*.; 1994, Fontana, 1996; Bueno *et al*., 2007). Stratigraphic and paleogeographic studies (e.g.; Holz *et al*., 2006, 2009) have conclusively shown that the configuration of the Paraná Basin in northeastern Rio Grande do Sul state was actually extended toward the present shoreline, and therefore the assumption that Paraná Basin rocks form the basement of the northern Pelotas Basin is valid and implies in economic aspects (e.g, the deep burial of Irati shales as source rock for hydrocarbons or the CBM potential of coal seams in greater depth than in the onshore region).

The present paper deals with the interpretation of the seismic expression of that zone integrated with magnetic studies, in order to investigate under the geophysical viewpoint if the basement of the Pelotas Basin is actually formed by rocks of the Paraná Basin and to what extend this occur.

Seismic data and interpretation

The continental crust underneath the basin was subjected to a rapid process of stretching and has developed variable degrees of deformation, and consequently shows seismic reflectors with variable signature. Crystalline rocks of the Precambrian basement are intensely stretched and deformed, whereas the sedimentary succession shows a characteristic chaotic pattern, while less stretched material and layered sedimentary successions show more parallel/subparallel patterns of seismic reflectors.

These two different seismic signatures were used to evaluate to what extent the continental crust and the overlying rocks of the Paraná Basin might be preserved in the study area. Insofar, the seismic lines should:

1 - Reveal the existence of continental crust in the entire off-shore area studied;

2 – Reveal the occurrence of seismic reflectors which could be linked to a sedimentary succession in a stratigraphic position below the volcanic rocks of the Serra Geral Formation and the rift-related basalts.

The National Petroleum Agency of Brazil (ANP) granted access to five 2D seismic lines located within the study area, of which three are dip and two are strike-orientated. Their lateral extend vary from 220 to 310 km, and a seismic depth of 7 seconds double travel-time. No time-depths converted seismic data is available.

In seismic lines 1 to 4 (Figures 2 A to E and 3A/B) the continental crust can be clearly mapped, and no evidence of oceanic crust can be seen. The analysis of the four seismic lines permits the conclusion that the continental crust extends off-shore and forms the basement of the study area.

Seismic line 5 (Fig. 3C and D) is located in the northern part of the study area, close to the limit of the Pelotas Basin and outside the area, where sediments of the Paraná Basin are expected. In this line the contact between continental and oceanic crust can be mapped, b SDRs appear clearly at the eastern part of the seismic line.

By specifically analyzing seismic lines 01 (Fig.4 A/B) and 02 (Fig. 4 C/D), which are partly crossing the off-shore area in question, one can depicture parallel to subparallel reflectors underneath the volcanic packages. These reflectors are no multiples, but the probable seismic record of layered and not very deformed sedimentary succession, suggesting the presence of a layered sedimentary package, which is interpreted as the record of Paraná Basin's rock succession.

The overall conclusion of the interpretation of the seismic lines is that:

A – Continental crust is the basement in the entire study area;

B – There is evidence of layered packages which are interpreted as the volcano-sedimentary succession of the Paraná Basin.

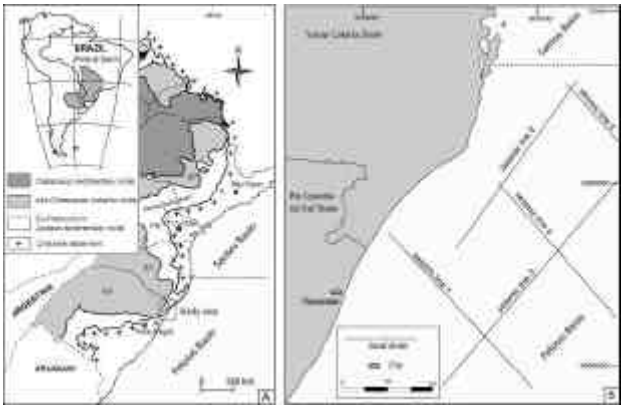

Figure 1 - Location map of the northern Pelotas Basin and the Paraná Basin, enhancing the study area and several off-shore seismic lines which are discussed in the present paper (modified from Holz *et al*.; 2009).

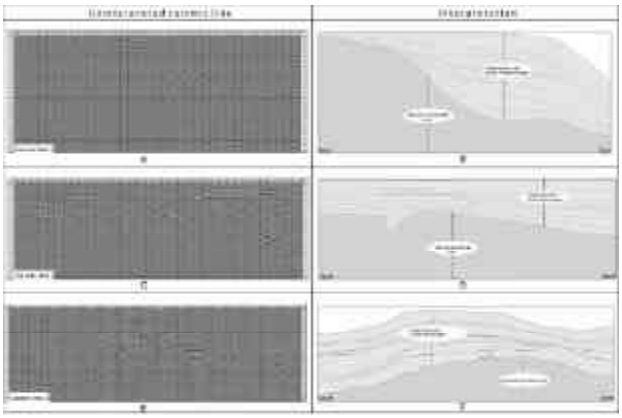

Figure 2 – (A) uninterpreted dip-directed seimic line 1 and (B) its geological interpretation, enhancing the contact of the stretched continental crust and the Pelotas Basin's sedimentary pile. No evidence of oceanic crust (i.e., SDRs) is seen in this section. Note unparallel reflectors at the left, interpreted as reminiscences of the sedimentary succession of the Paraná Basin. (C) uninterpreted strike-directed seismic line 2 and (D) its geological interpretation, enhancing the contact of the stretched continental crust and the Pelotas Basin's sedimentary pile. The depression is a rift valley. (E) uninterpreted strike-directed seismic line 3 and (B) its geological interpretation, enhancing the contact of the stretched continental crust and the Pelotas Basin's sedimentary pile. The elevation is an Oligocene-Micocene sedimentary structure known as the Rio Grande High (modified from Holz *et al*.; 2009).

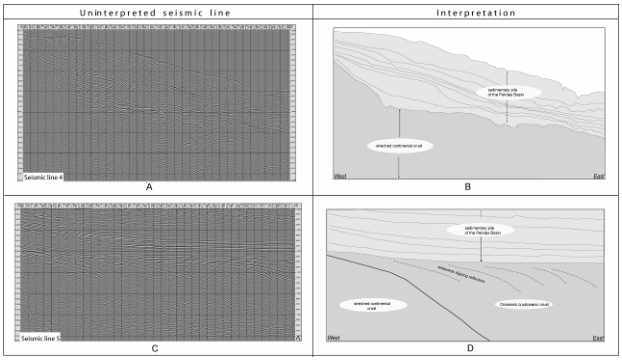

Figure 3 – (A) uninterpreted dip-directed seismic line 4 and (B) its geological interpretation, enhancing the contact of the stretched continental crust and the Pelotas Basin's sedimentary pile. (C) uninterpreted dip-directed seismic line 5 and (D) its geological interpretation, enhancing the contact of the stretched continental crust with the oceanic crust and the overlying Pelotas Basin's sedimentary pile. Note the seawards dipping reflectors, a secure indicator of initial oceanic crust (modified from Holz *et al*.; 2009).

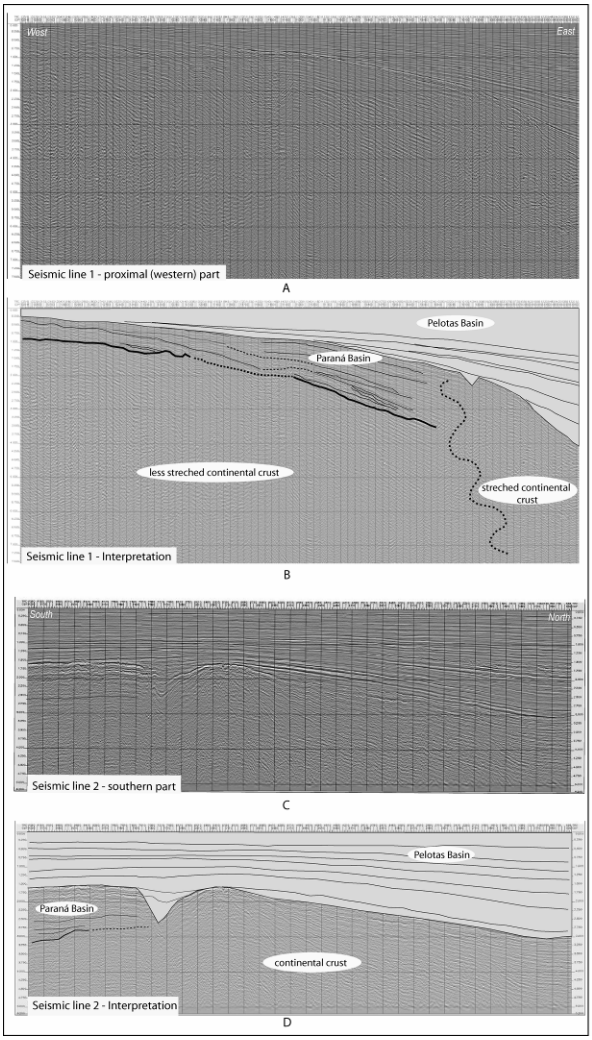

Figure 4 – (A) and (B) are show dip-directed seismic line 1, (C) and (D) show line 2. In both lines some parallel to unparallel reflectors underneath the volcanic packages can be depictured. These reflectors are no multiples, but the probable seismic record of layered and not very deformed sedimentary succession, suggesting the presence of a layered sedimentary package which is interpreted as the Paraná Basin's succession (modified from Holz *et al*.; 2009).

Magnetic data and interpretation

The National Petroleum Agency of Brazil (ANP) granted access to two aeromagnetic surveys, which cover the study area. The magnetic data were acquired at the end of 1960s for a 170 to 200 km broad belt covering the northern part of the Pelotas Basin and the entire adjacent Santos Basin to the north, with a line spacing of 5 km, perpendicular to the coast line, with a sample interval of 60 m and flight height around 150m.

The integrated magnetic map (Figure 5) is characterized by a set of anomalies of regional sources with overlying high frequency lineaments, which occur between the bathymetry of 50 and 75 m, which are linked to dike swarms and seawards-dipping reflectors.

The magnetic responses within the study area suggest absence of oceanic crust due to the absence of higher amplitude anomalies from deep-lying sources, confirming the geologic interpretation of the basement as shown by the before discussed seismic lines. There are few magnetic lineaments with higher frequency signals, approximately 30 km width and 200 km length.

This interpretation is strengthened by the application of upward continuation filter in 2000 m (Fig. 6), indicating that in the study area the magnetic sources are deeper (> 2000m) than in the adjacent areas to the north and south, where high amplitude anomalies of less deeper sources (< 2000m) are evident.

The difference of the magnetic signature within the study area is interpreted as an additional evidence that in the study area a part of the Paraná Basin exists: the crystalline basement is deeper here than in the adjacent areas to the north and south, where the sedimentary pile of the Pelotas Basin is in direct contact with the basement. Therefore, the sedimentary pile of the

Paraná Basin present in the study area causes the source of the magnetic signal to be deeper than in the adjacent areas.

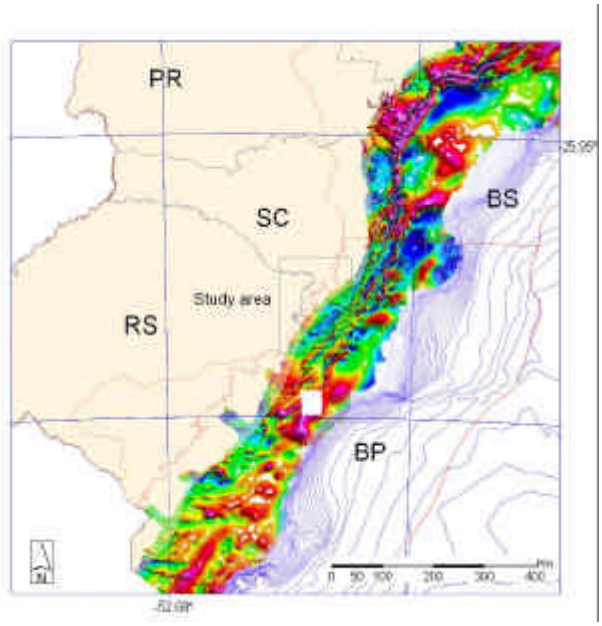

Figure 5 – Magnetic map of southern Brazil, characterized by a set of anomalies of regional sources with overlying high frequency lineaments which occur between the bathymetry of 50 and 75 m, interpreted as contribution of sources linked to dike swarms and seawards-dipping reflectors. (BP = Pelotas Basin, BS = Santos Basin) (Modified from Holz *et al*.; 2009).

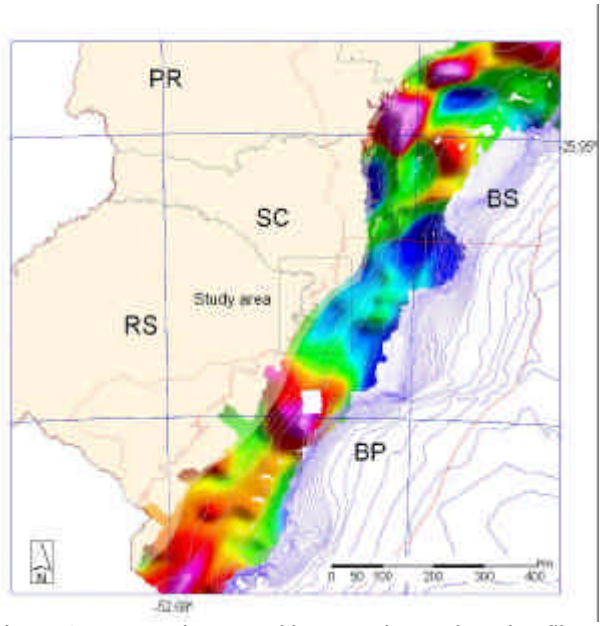

Figura 6 - Magnetic map with upwards continuation filter, showing that in the study area the magnetic sources are deeper (> 2000m) than in the adjacent areas to the north and south, where high amplitude anomalies of less deeper sources (< 2000m) are evident. The area with deep-lying magnetic sources – reflex of a deeper basement than in the adjacent areas. This coincides with the area where the presence of the sedimentary succession of the Paraná Basin is expected. (BP = Pelotas Basin, BS = Santos Basin) (Modified from Holz *et al*.; 2009).

Conclusions

Several lines of evidence point to the fact that the sedimentary pile of the Paraná Basin extends into the present day off-shore regions of northern Rio Grande do Sul and southern Santa Catarina States. The majority of the basement of the study area has continental crust, only in the northeastern zone oceanic crust is mapped. This indicates that the continental crust of the study area is stretched in variable degrees.

Data provided from seismic interpretation shows that the entire study area clearly has continental crust as its basement, and has several lines that are parallel to subparallel reflectors, suggesting the existence of layered rocks.

The magnetic data also provies evidence that in the study area the crystalline basement is deeper than in the adjacent areas to the north and south, where the sedimentary pile of the Pelotas Basin is in direct contact with the basement.

In order to make a more precise estimation and to delimit exploration areas for hydrocarbon or CBM, the following strategies are recommended:

1 – The existing seismic lines have to be re-processed for deeper intervals (at least the interval between 3 and 6 second double travel time)

2 – New seismic lines should be acquired, enhancing the seismic coverage of the area, which actually is relatively poor.

Acknowledgments

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